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(54) **Megoldás turbókompresszor szabályozására**

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(54) **A SOLUTION FOR CONTROLLING A TURBO COMPRESSOR**
LÖSUNG ZUR STEUERUNG EINES TURBOKOMPRESSORS
SOLUTION POUR COMMANDE DE TURBOCOMPRESSEUR

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EP 2 593 648 B1

Description

Field of the invention

[0001] The present invention relates to a system and a method for controlling an actuator, particularly a turbo compressor. The invention also relates to an actuator comprising at least one turbo compressor, with an outlet in said at least one turbo compressor for conveying compressed gas to at least one cooler, and a shaft for rotating said at least one turbo compressor, for increasing the pressure of the gas to be supplied to the actuator. The actuator according to the invention relates to a turbo-type compressor in which the blades of the turbo wheels rotate at a high speed and thereby increase the pressure of the gas. The pressure increase may take place at one or more stages.

Background of the invention

[0002] Primarily, two types of compressors are known: positive displacement compressors and dynamic compressors. The positive displacement compressors include, for example, screw compressors, piston compressors, and vane compressors. The positive displacement compressors are also called static compressors. The dynamic compressors, in turn, can be divided into the centrifugal and axial flow types (radial compressors and axial compressors, respectively). In dynamic compressors, air is provided with high kinetic energy which is then converted to pressure. Dynamic compressors can also be called turbo compressors.

[0003] In known solutions for controlling turbo compressors, the quantity of air and the pressure increase produced by the turbo compressor are adjusted, among other things, by guide vanes installed at the air intake of the turbo compressor, by diffuser vanes installed downstream of the impeller wheel, by changing the rotating speed of the actuator, by recirculating some of the air from the pressure side back to the suction side, or by blowing some of the compressed air out of the process via a valve.

[0004] Known methods for adjusting turbo compressors relating to combustion engines and their turbo drives are presented in technical literature in the field, publications of turbo compressor manufacturers, as well as patent publications, for example Japanese patent application publication JP 2008286039 A as well as international patent application publication WO 1999049222 A1.

[0005] FR 2 040 794 A5 discloses a turbocompressor arrangement comprising at least one cooler, at least one turbo compressor stage with an outlet for conveying gas compressed in said one turbo compressor stage to said at least one cooler, a shaft for rotating said at least one stage of turbo compressor for increasing the pressure of the gas to be supplied to the actuator, a turbine and a control valve, by means of which the flow of compressed gas produced by the turbo compressor to the turbine is arranged to be adjusted.

[0006] Some drawbacks of the known solutions for controlling turbo compressors include, for example, the fact that they have a narrower range of capacity control compared with, for example, the range of capacity control of screw compressors, as well as the fact that when applying them, the total efficiency of the process and the actuator is lower, because of e.g. fluctuation in the need of gas, compared with *e.g.* the efficiency of screw compressors.

[0007] The control solution disclosed in patent publication JP 2008286039 A is designed particularly for preventing stall of turbo compressors in combustion engines, not for producing oilless compressed air with turbo compressors.

[0008] In the invention disclosed in publication WO 19990/44222 A1, the solution for generating pressure by a turbine is implemented by integrating a turbine unit in one compressor unit, which corresponds to a turbocharger structure known as such. The other compressor units are provided with separate motor units of their own. These motor units may be either with or without a step-up gear. In the solution according to said publication, superfluous air/gas, in other words air/gas that is momentarily not needed in the process, is continuously led to the turbine to provide the shaft output needed by one compressor unit. Consequently, this solution does not make it possible to adjust the production of compressed air in a wide adjustment range without changing an operating point, such as the efficiency or the rotating speed, of the compressor units.

Brief summary of the invention

[0009] It is an aim of the invention relating to this patent application to eliminate the above-mentioned drawbacks of prior art solutions for controlling turbo compressors, and to present an improvement in the ways of producing the quantity of gas and the control systems therein, with respect to the prior art. The device according to the invention as defined in claim 1 can be used to supplement the output adjustment achieved by means of the operating speed more widely, possibly even down to zero output, and simultaneously to reduce the energy consumption by recovering energy produced in the expansion of gas in the turbine wheel, back to the process.

[0010] The device according to an advantageous embodiment of the invention operates in such a way that gas that has already been compressed is led via a valve to the turbine wheel, where the gas, when expanding, rotates the turbine by means of said turbine wheel and returns some energy needed to compress the gas

[0011] The turbine wheel can be placed on the same shaft with one or more turbo wheels compressing the gas, or on a separate shaft, to rotate the generator or the turbo wheel, or a combination of these.

[0012] In a multistage turbo compressor, the gas for the turbine wheel can be supplied from any stage either upstream or downstream of the inter- and aftercoolers.

[0013] The device according to the invention can also be built in the same housing with the turbo compressor both in the single-stage and multistage implementations.

[0014] To put it more precisely, the actuator according to the present invention is primarily characterized in that the actuator further comprises a turbine and a control valve by which the flow of compressed gas generated by the turbo compressor to the turbine is arranged to be controlled.

[0015] The method according to the present invention as defined in claim 12 is primarily characterized in that the actuator further comprises a turbine and a control valve, wherein, in the method, the flow of compressed gas produced by the turbo compressor to the turbine is controlled by said control valve.

[0016] The control system according to the present invention as defined in claim 13 is primarily characterized in that the control system further comprises a turbine and a control valve by which the flow of compressed gas generated by the turbo compressor to the turbine is arranged to be controlled.

[0017] In the actuator according to the invention, the adjustment is made at a constant rotating speed or by changing the rotating speed to only such an extent that the efficiency of the actuator or the delivery pressure is not substantially disturbed. When the pressure starts to rise in the process, that is, the need of gas is reduced, the valve between or after the different stages in the turbo compressor is opened, wherein part of the air flow is guided to an actuator, such as a turbine unit integrated in the turbo compressor unit, or a separate turbine unit. Thus, if the turbine unit is mounted on the same shaft as the turbo compressor, the power required by the motor is reduced. If the turbine unit is mounted on a separate generator shaft, the generator rotated by the turbine unit can be used to recover electric power into the process.

[0018] The most significant differences of this invention to the technical solution presented in patent publication JP 2008286039 A relate to the utilization of superfluous process air/gas in generating the shaft output required for the operation of the turbo compressors.

[0019] In the solution according to the present application, the quantity of gas passing through the turbo compressors remains almost constant, wherein the operation can always take place in the best possible efficiency range. In the solution presented in the patent publication JP 2008 286039 A, the superfluous air/gas circulated through the turbine is returned to the compressor unit, wherein the quantity of the air/gas flowing through the compressor (and the rotating speed of the compressor) is always changed when the process is adjusted, and consequently, the compressor rarely operates in the optimum efficiency range.

[0020] Compared with the solution presented in the publication WO 19990/44222 A1, the solution according to the present invention has, among other things, the advantage that the conveying of superfluous air/gas, which is momentarily not needed in the process, to the turbine can be adjusted, which thus makes it possible to adjust the output of compressed air in a wide adjustment range without a need to change the operating point of the turbo compressor units.

Description of the drawings

[0021] In the following, the invention will be described in more detail with reference to the appended drawings, in which

Fig. 1a shows a control system according to a preferred embodiment of the invention in a reduced chart,

Fig. 1b shows a device according to a second advantageous embodiment of the invention in a reduced chart,

Fig. 1c shows a device according to a third advantageous embodiment of the invention in a reduced chart,

Fig. 1d shows a device according to a fourth advantageous embodiment of the invention in a reduced chart,

Fig. 2 shows control characteristic curves for a device according to an advantageous embodiment of the invention,

Fig. 3 shows a process system in which the invention can be applied, and

Fig. 4 shows the method according to a preferred embodiment of the invention in a flow chart.

Detailed description of the invention

[0022] Figure 1 a shows a control system according to an advantageous embodiment of the invention for controlling an actuator 10, in a reduced chart. The actuator 10 is, for example, a turbo compressor comprising a motor 5 and turbo compressors 1 a, 1 b arranged in connection with a shaft 5a of the motor 5. These turbo compressors 1 may be impellers or the like, whose rotating movement produces an increase in the pressure of air or another gas; in other words, the gas is compressed to a smaller volume. The turbo compressor 10 also comprises one or more coolers 3a, 3b connected between the compressors 1 in the compressed air system. Furthermore, the turbo compressor 10 comprises a turbine 2 and a control valve 4. Moreover, the turbo compressor 10 is provided with an intake 6 for conveying air or gas into the turbo compressor 10 and, correspondingly, an outlet 7 for conveying compressed air out of the turbo compressor 10, for example to a process 11. The turbine

2 can also be provided with an outlet 8 for discharging air or gas from the turbine 2.

[0023] We shall now describe the operation of the system according to Fig. 1 a with reference to the flow chart of Fig. 4. Air or other gas is supplied into the turbo compressor 10 via the intake 6, from which the air or other gas is conveyed to a first stage of turbo compressor 1a (block 401 in Fig. 4). The rotating movement of the shaft 5a of the motor 5 also generates the rotation of the turbo compressors 1 a, 1 b. Thus, the movement of the impeller of the turbo compressor 1 a, 1 b increases the pressure and the temperature of the gas (block 402). The compressed gas is led via the outlet 1 c of the first stage of turbo compressor and a flow channel 12 to a first cooler 3a, in which the temperature of the gas is lowered (block 403). From the first cooler 3a, the gas is conveyed to a second stage of turbo compressor 1 b, for example via an intake 1 d (block 404). The impeller wheel of the second turbo compressor 1 b is also in connection with the motor shaft 5a, wherein the rotating movement of the motor shaft 5a generates the rotation of the impeller wheel, which increases the gas pressure further. From the second stage of turbo compressor 1 b, the compressed gas is led, for example via an outlet 1 e, to a second cooler 3b for lowering the gas temperature (block 405). From the second cooler 3b, the compressed gas can be led via an outlet 7 for example to the process 11 (block 406).

[0024] In a situation in which the pressure starts to rise in the process 11, that is, the gas demand in the process 11 decreases, the control valve 4 can be used to direct part of the gas in the turbo compressor 10 to the turbine 2 (block 407). In the device shown in Fig. 1a, this gas flow to the turbine 2 has the effect that the turbine 2 reduces the need for power supply in the motor 5; in other words, the turbine 2 in a way returns part of the energy needed for compressing the gas, to the motor shaft 5a. That part of the gas which was led to the turbine can be conveyed via the outlet 8 of the turbine, for example to the atmosphere, or back to the intake 6 of the turbo compressor.

[0025] When the pressure in the process 11 begins to decline, the control valve 4 can be adjusted in the closing direction or totally closed, wherein the amount of gas to be led to the turbine 2 is reduced or the supply of gas to the turbine 2 is cut off. If there is need for adjustment again, this can be done in the above-described manner by means of the control valve 4. In this way, the power control and simultaneously the efficiency of the system can also be adjusted, in addition to adjusting the rotating speed of the motor 5, by directing part of the gas to the turbine 2.

[0026] During the adjustment, changing the rotating speed of the motor shaft 5 is either not necessary at all or is only necessary to such an extent that the efficiency or the delivery pressure of the turbo compressor 10 is not substantially reduced.

[0027] The above-mentioned steps can be repeated, if necessary.

[0028] In the embodiment shown in Fig. 1a, the turbine 2 is arranged on the same shaft with the compressors 1 a, 1 b. This shaft is advantageously the motor shaft 5a, but it may also be another shaft which is in a power transmitting connection with the motor shaft 5a. The arrangement of Fig. 1 a can also be implemented in such a way that a generator is also coupled to the shaft connecting the turbine 2 and the turbo compressors 1 a, 1 b, to generate electric power particularly in a situation in which gas is utilized for rotating the turbine 2. This electric power can be supplied, for example, to the motor 5 or to the process 11 (Fig. 3).

[0029] Figure 1b shows a control system according to another advantageous embodiment of the invention. The difference to the embodiment of Fig. 1 a lies primarily in that the turbine 2 is not connected to the motor shaft 5a but it is implemented as a separate element. Thus, the turbine 2 is arranged to rotate the generator 9. Thus, in a situation in which part of the gas is led via the control valve 4 to the turbine 2, the rotational motion of the turbine 2 has the effect that the generator generates electric power which can be supplied to the motor 5. This reduces the amount of electric power required by the motor 5 from another energy source.

[0030] Figure 1c shows a control system according to a third advantageous embodiment of the invention. The difference to the embodiment of Fig. 1a lies primarily in that the gas supplied to the turbine 2 is cooled in a cooler 3c. Thus, the temperature of the gas output from the turbine 2 may be lower than in a situation in which no cooler 3c is used. It is obvious that the cooler 3b can also be implemented in the embodiment shown in Fig. 1b by including the cooler between the outlet of the control valve 4 and the intake of the turbine 2.

[0031] Figure 1d shows a control system according to a fourth advantageous embodiment of the invention. The difference to the embodiment of Fig. 1 b lies primarily in that the turbine 2 is connected not to the generator but to the first stage of turbo compressor 1 a; in other words, the turbine 2 is arranged to rotate the first stage of turbo compressor 1 a. Thus, in a situation in which part of the gas is led via the control valve 4 to the turbine 2, the rotational motion of the turbine 2 makes the impeller wheel of the first stage of turbo compressor 1 a rotate, wherein the first stage of turbo compressor 1 a raises the pressure of the incoming gas. In some embodiments, power can be transmitted to the first stage of turbo compressor 1 a from both the motor 5 and the turbine 2. Such a combined power transmission arrangement may require a gear system or the like, by which the power transmitted from two different power sources can be transferred in a controlled manner to the first stage of turbo compressor 1 a.

[0032] As can be found from the description above, the control system according to the invention can be used to achieve better adjustment and a wider adjustment range than in the prior art.

[0033] Although two turbo compressor stages were applied in the embodiments described above, it is obvious that there may also be more than two stages, for example three, four or more stages.

[0034] Figure 2 shows an example of control characteristic curves. The horizontal axis and the vertical axis represent the quantity of volume flow and the pressure, respectively. The value X of the volume flow represents the projected value (100%), and the pressure value Y represents the corresponding target pressure. The curve A depicts the characteristic curve of a turbo compressor system of prior art (ratio of volume flow to pressure) at a rotational speed n_0 of the motor, the curve B depicts the characteristic curve of the system at a given maximum rotational speed n_1 higher than the rotational speed n_0, and the curve C depicts the characteristic curve of the system at a given minimum rotational speed n_{-1} lower than the rotational speed n_0. The letter Z indicates a volume flow/pressure ratio that can be achieved by the system according to the invention, the corresponding rotational speed of the motor shaft 5a being n_{-1}. In a device of prior art, the adjustment of the rotational speed n can be used to reduce the volume flow by only a few percent lower than the projected value of 100%. In the solution according to the invention, it is possible to achieve a value of less than a half, in an advantageous embodiment even a value of about 20% of the projected value, without having to reduce the rotational speed significantly. Thus, a good efficiency is achieved.

[0035] In some advantageous embodiments, the projected pressure value can be in the order of 6 to 10 bar, but it may also be higher than that, for example 13 bar, or lower than that, even lower than 1 bar.

[0036] The present invention is suitable for use in a very wide power range. The power of the turbo compressor 10 may be, for example, between 100 kW and 1 MW, but it may also be lower than 100 kW or even higher than 1 MW.

[0037] Figure 3 shows yet another example of the process 11, in which the actuator according to the invention can be used. The process 11 may be any process in which compressed gas is needed. The process 11 or the outlet 7 of the turbo compressor 10 is provided with, for example, a pressure sensor 12 or the like, for measuring the pressure of the gas supplied into the process 11. The measurement data given by the pressure sensor 12 is transmitted to a control unit 13 which may, for example, compare the measurement data with a reference value and determine, on the basis of the comparison, for example if there is a need to adjust the control valve 4. If it is found that the pressure has exceeded the reference value, the control unit 13 transmits information that the control valve 4 has to be opened, to the control means 4a of the control valve 4. In some embodiments, the control unit 13 may directly generate a signal, for example a voltage, which effects a change in the position of the control valve 4. In such a case, the control means 4a for the control valve is not necessary.

[0038] Correspondingly, in a situation in which the pressure has declined, for example, to a given limit value, the control unit 13 may control the control valve 4 in the closing direction, which reduces or totally prevents the flow of gas to the turbine 2.

[0039] It is obvious that the control valve 4 may also have other positions than the open and closed positions, wherein, according to the situation, the quantity of gas to be led to the turbine 2 may also be somewhere between the maximum and minimum values.

[0040] Even though it was presented above that the gas is supplied to the turbine 2 downstream of the second stage of turbo compressor 1 b, in a multistage turbo compressor the gas can be supplied from any stage either upstream or downstream of the inter- and aftercoolers 1 a, 1 b.

[0041] The device according to the invention can also be built in the same housing with the turbo compressor in both the single-stage and multistage implementations.

[0042] In some embodiments, all or part of the gas that has flowed through the turbine 2 unit can be utilized for cooling the motor 5 of the turbo compressor, auxiliary devices, and/or the gas produced by the turbo compressor 10.

[0043] In some embodiments of the invention, the adjustment of the compressors 1 a, 1 b and the turbine 2 is implemented by utilizing high speed technology, in which the peripheral speeds of the actuators are typically even 100 m/s or higher. For example, a high speed motor can be used as the motor 5.

[0044] In some embodiments of the invention, the bearings of the compressors 1a, 1 b, the turbine 2 and/or the motor 5 can be implemented with, for example, air bearings, gas bearings, or so-called hybrid bearings, that is, as a combination of an air or gas bearing and a magnet bearing.

[0045] It is obvious that the present invention is not limited solely to the above-presented embodiments but it can be modified within the scope of the appended claims.

Claims

1. An actuator (10) comprising:

   - at least one cooler (3a, 3b);
   - at least one turbo compressor stage (1a, 1b) with an outlet for conveying gas compressed in said at least one turbo compressor stage (1a, 1b) to said at least one cooler (3a, 3b);
   - a shaft (5a) for rotating said at least one stage of turbo compressor (1a, 1b) for increasing the pressure of the gas to be supplied to the actuator (10);
   - a turbine (2); and
   - a control valve (4), by means of which the flow of compressed gas produced by the turbo com-

pressor (1a, 1b) to the turbine (2) is arranged to be adjusted,

characterized in that the actuator further comprises a motor (5) arranged to rotate said shaft (5a), and that the actuator is adapted to use the gas that has flowed through the turbine (2) for cooling at least one of the following:

- the motor (5) of the turbo compressor;
- an auxiliary device.

2. The actuator (10) according to claim 1, **characterized in that** said turbine (2) is connected to said shaft (5a).

3. The actuator (10) according to claim 2, **characterized in that** the actuator (10) further comprises a generator (9) connected to said shaft (5a).

4. The actuator (10) according to claim 1, **characterized in that** the actuator (10) further comprises a generator (9) arranged in a power transmitting connection with the turbine (2).

5. The actuator (10) according to any of the claims 1 to 4, **characterized in that** the actuator (10) comprises at least a first turbo compressor (1a) with said gas outlet (1c), and a second stage of turbo compressor with a gas intake (1d), and a first cooler (3a) connected between the outlet (1c) of the first stage of turbo compressor and the intake (1d) of the second turbo compressor.

6. The actuator (10) according to claim 5, **characterized in that** said control valve (4) is arranged to convey gas from the first cooler (3a) to the turbine (2).

7. The actuator (10) according to any of the claims 1 to 4, **characterized in that** the actuator (10) comprises at least a first stage of turbo compressor (1a) with said gas outlet (1c), and a second stage of turbo compressor with a gas intake (1d) and a gas outlet (1e), a first cooler (3a) connected between the outlet (1c) of the first stage of turbo compressor and the intake (1d) of the second stage of turbo compressor, and a second cooler (3b) connected between the outlet (1e) of the second turbo compressor and the outlet (7) of the actuator.

8. The actuator (10) according to claim 6, **characterized in that** said control valve (4) is arranged to convey gas from the second cooler (3b) to the turbine (2).

9. The actuator (10) according to any of the claims 1 to 8, **characterized in that** the motor (5) is a high speed motor.

10. The actuator (10) according to any of the claims 1 to 9, **characterized in that** the bearings of the turbine (2) and/or the motor (5) comprise air bearings, gas bearings, or a combination of an air or gas bearing and a magnet bearing.

11. The actuator (10) according to any of the claims 1 to 10, **characterized in that** the actuator (10) further comprises a cooler (3c) connected between the turbine (2) and the control valve (4).

12. A method for controlling an actuator (10), which actuator (10) comprises at least one cooler (3a, 3b), at least one turbo compressor (1a, 1b) with an outlet for conveying gas compressed in said at least one turbo compressor (1a, 1b) to at least one cooler (3a, 3b), a turbine (2), a control valve (4), and a shaft (5a) to which said at least one turbo compressor (1a, 1b) is connected, wherein in the method the shaft (5a) is rotated to raise the pressure of the gas to be supplied to the actuator (10), and the flow of compressed gas produced by the turbo compressor (1a, 1b) to the turbine (2) is adjusted by means of said control valve (4), **characterized in that** the method further comprises using a motor (5) to rotate said shaft (5a), and using the gas that has flowed through the turbine (2) for cooling at least one of the following:

- the motor (5) of the turbo compressor;
- an auxiliary device.

13. A control system for an actuator (10), which actuator (10) comprises:

- at least one cooler (3a, 3b);
- at least one stage of turbo compressor (1a, 1b) with an outlet for conveying gas compressed in said at least one stage of turbo compressor (1a, 1b) to at least one cooler (3a, 3b),
- a shaft (5a) for rotating said at least one stage of turbo compressor (1a, 1b) for raising the pressure of the gas to be supplied to the actuator (10),
- a turbine (2), and
- a control valve (4), by means of which the flow of compressed gas produced by the turbo compressor (1a, 1b) to the turbine (2) is arranged to be adjusted,

characterized in that the control system further comprises a motor (5) arranged to rotate said shaft (5a), and that the control system is adapted to use the gas that has flowed through the turbine (2) for cooling at least one of the following:

- the motor (5) of the turbo compressor;
- an auxiliary device.

Patentansprüche

1. Betätigungseinrichtung (10), umfassend:

- wenigstens eine Kühleinrichtung (3a, 3b);
- wenigstens eine Turbokompressorstufe (1 a, 1 b) mit einem Auslass zum Fördern von Gas, das in der wenigstens einen Turbokompressorstufe (1 a, 1 b) komprimiert wurde, zu der wenigstens einen Kühleinrichtung (3a, 3b);
- eine Welle (5a) zum Drehen der wenigstens einen Stufe des Turbokompressors (1 a, 1 b) zum Erhöhen des Drucks des der Betätigungseinrichtung (10) zuzuführenden Gases;
- eine Turbine (2); und
- ein Steuerventil (4), durch das der Strom von Druckgas, das von dem Turbokompressor (1 a, 1 b) erzeugt wurde, zur Turbine (2) so angeordnet wird, dass er eingestellt wird,

dadurch gekennzeichnet, dass die Betätigungseinrichtung ferner einen Motor (5) umfasst, der so angeordnet ist, dass er die Welle (5a) dreht, und dass die Betätigungseinrichtung dazu geeignet ist, das Gas, das durch die Turbine (2) geströmt ist, zur Kühlung wenigstens eines der Folgenden zu verwenden:

- des Motors (5) des Turbokompressors;
- einer Zusatzvorrichtung.

2. Betätigungseinrichtung (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Turbine (2) mit der Welle (5a) verbunden ist.

3. Betätigungseinrichtung (10) nach Anspruch 2, **dadurch gekennzeichnet, dass** die Betätigungseinrichtung (10) ferner einen Generator (9) umfasst, der mit der Welle (5a) verbunden ist.

4. Betätigungseinrichtung (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Betätigungseinrichtung (10) ferner einen Generator (9) umfasst, der in einer Energieübertragungsverbindung mit der Turbine (2) steht.

5. Betätigungseinrichtung (10) nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** die Betätigungseinrichtung (10) wenigstens einen ersten Turbokompressor (1 a) mit dem Gasauslass (1 c) sowie eine zweite Stufe des Turbokompressors mit einem Gaseinlass (1d) und eine erste Kühleinrichtung (3a) umfasst, die zwischen dem Auslass (1c) der ersten Stufe des Turbokompressors und dem Einlass (1d) des zweiten Turbokompressors angeschlossen ist.

6. Betätigungseinrichtung (10) nach Anspruch 5, **dadurch gekennzeichnet, dass** das Steuerventil (4) so angeordnet ist, dass es Gas von der ersten Kühleinrichtung (3a) zur Turbine (2) fördert.

7. Betätigungseinrichtung (10) nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** die Betätigungseinrichtung (10) wenigstens eine erste Stufe des Turbokompressors (1 a) mit dem Gasauslass (1c) sowie eine zweite Stufe des Turbokompressors mit einem Gaseinlass (1d) und einem Gasauslass (1 e) umfasst, wobei eine erste Kühleinrichtung (3a) zwischen dem Auslass (1c) der ersten Stufe des Turbokompressors und dem Einlass (1d) der zweiten Stufe des Turbokompressors angeschlossen ist, und eine zweite Kühleinrichtung (3b) zwischen dem Auslass (1 e) des zweiten Turbokompressors und dem Auslass (7) der Betätigungseinrichtung angeschlossen ist.

8. Betätigungseinrichtung (10) nach Anspruch 6, **dadurch gekennzeichnet, dass** das Steuerventil (4) so angeordnet ist, dass es Gas von der zweiten Kühleinrichtung (3b) zur Turbine (2) fördert.

9. Betätigungseinrichtung (10) nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet, dass** der Motor (5) ein Hochgeschwindigkeitsmotor ist.

10. Betätigungseinrichtung (10) nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet, dass** die Lager der Turbine (2) und/oder des Motors (5) Luftlager, Gaslager oder eine Kombination aus einem Luft- oder Gaslager und einem Magnetlager umfassen.

11. Betätigungseinrichtung (10) nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet, dass** die Betätigungseinrichtung (10) ferner eine Kühleinrichtung (3c) umfasst, die zwischen der Turbine (2) und dem Steuerventil (4) angeschlossen ist.

12. Verfahren zum Steuern einer Betätigungseinrichtung (10), wobei die Betätigungseinrichtung (10) wenigstens eine Kühleinrichtung (3a, 3b), wenigstens einen Turbokompressor (1 a, 1 b) mit einem Auslass zum Fördern von Gas, das in dem wenigstens einen Turbokompressor (1a, 1 b) komprimiert wurde, zu wenigstens einer Kühleinrichtung (3a, 3b), eine Turbine (2), ein Steuerventil (4) und eine Welle (5a), an die der wenigstens eine Turbokompressor (1 a, 1 b) angeschlossen ist, umfasst, wobei in dem Verfahren die Welle (5a) gedreht wird, um den Druck des der Betätigungseinrichtung (10) zuzuführenden Gases zu erhöhen, und der Strom von Druckgas, das von dem Turbokompressor (1 a, 1 b) erzeugt wird, zur Turbine (2) mittels des Steuerventils (4) eingestellt wurde, **dadurch gekennzeichnet, dass** das Verfahren ferner das Verwenden eines Motors (5) zum Drehen der Welle (5a) und das Verwenden des Gases, das durch die Turbine (2) geströmt ist, zum Kühlen wenigstens eines der Folgenden umfasst:

- des Motors (5) des Turbokompressors;
- einer Zusatzvorrichtung.

13. Steuerungssystem für eine Betätigungseinrichtung (10), wobei die Betätigungseinrichtung (10) umfasst:

- wenigstens eine Kühleinrichtung (3a, 3b);
- wenigstens eine Stufe eines Turbokompressors (1 a, 1 b) mit einem Auslass zum Fördern von Gas, das in der wenigstens einen Stufe des Turbokompressors (1 a, 1 b) komprimiert wurde, zu wenigstens einer Kühleinrichtung (3a, 3b),
- eine Welle (5a) zum Drehen der wenigstens einen Stufe des Turbokompressors (1 a, 1 b) zum Erhöhen des Drucks des der Betätigungseinrichtung (10) zuzuführenden Gases;
- eine Turbine (2), und
- ein Steuerventil (4), durch das der Strom von Druckgas, das von dem Turbokompressor (1 a, 1 b) erzeugt wurde, zur Turbine (2) so angeordnet wird, dass er eingestellt wird,

dadurch gekennzeichnet, dass die Steuerungseinrichtung ferner einen Motor (5) umfasst, der so angeordnet ist, dass er die Welle (5a) dreht, und dass die Steuerungseinrichtung dazu geeignet ist, das Gas, das durch die Turbine (2) geströmt ist, zur Kühlung wenigstens eines der Folgenden zu verwenden:

- des Motors (5) des Turbokompressors;
- einer Zusatzvorrichtung.

Revendications

1. Actionneur (10) comprenant :

- au moins un refroidisseur (3a, 3b) ;
- au moins un étage de turbocompresseur (1 a, 1 b) avec une sortie pour transporter un gaz compressé dans ledit au moins un étage de turbocompresseur (1 a, 1 b) jusqu'audit au moins un refroidisseur (3a, 3b) ;
- un arbre (5a) pour mettre en rotation ledit au moins un étage de turbocompresseur (1 a, 1 b) pour augmenter la pression du gaz devant être délivré à l'actionneur (10) ;
- une turbine (2) ; et
- une soupape de commande (4), au moyen de laquelle l'écoulement de gaz compressé produit par le turbocompresseur (1 a, 1 b) jusqu'à la turbine (2) est agencé pour être ajusté,

caractérisé en ce que l'actionneur comprend en outre un moteur (5) agencé pour mettre en rotation ledit arbre (5a), et **en ce que** l'actionneur est adapté à utiliser le gaz qui s'est écoulé à travers la turbine (2) pour refroidir au moins un des suivants :

- le moteur (5) du turbocompresseur ;
- un dispositif auxiliaire.

2. Actionneur (10) selon la revendication 1, **caractérisé en ce que** ladite turbine (2) est connectée audit arbre (5a).

3. Actionneur (10) selon la revendication 2, **caractérisé en ce que** l'actionneur (10) comprend en outre un générateur (9) connecté audit arbre (5a).

4. Actionneur (10) selon la revendication 1, **caractérisé en ce que** l'actionneur (10) comprend en outre un générateur (9) agencé dans une connexion de transmission de puissance avec la turbine (2).

5. Actionneur (10) selon l'une quelconque des revendications 1 à 4, **caractérisé en ce que** l'actionneur (10) comprend au moins un premier turbocompresseur (1 a) avec ladite sortie de gaz (1c), et un deuxième étage de turbocompresseur avec une admission de gaz (1d), et un premier refroidisseur (3a) connecté entre la sortie (1c) du premier étage de turbocompresseur et l'admission (1d) du deuxième turbocompresseur.

6. Actionneur (10) selon la revendication 5, **caractérisé en ce que** ladite soupape de commande (4) est agencée de manière à transporter le gaz du premier refroidisseur (3a) jusqu'à la turbine (2).

7. Actionneur (10) selon l'une quelconque des revendications 1 à 4, **caractérisé en ce que** l'actionneur (10) comprend au moins un premier étage de turbocompresseur (1 a) avec ladite sortie de gaz (1c), et un deuxième étage de turbocompresseur avec une admission de gaz (1 d) et une sortie de gaz (1 e), un premier refroidisseur (3a) connecté entre la sortie (1c) du premier étage de turbocompresseur et l'admission (1d) du deuxième étage de turbocompresseur, et un deuxième refroidisseur (3b) connecté entre la sortie (1 e) du deuxième turbocompresseur et la sortie (7) de l'actionneur.

8. Actionneur (10) selon la revendication 6, **caractérisé en ce que** ladite soupape de commande (4) est agencée de manière à transporter le gaz du deuxième refroidisseur (3b) jusqu'à la turbine (2).

9. Actionneur (10) selon l'une quelconque des revendications 1 à 8, **caractérisé en ce que** le moteur (5) est un moteur à grande vitesse.

10. Actionneur (10) selon l'une quelconque des revendications 1 à 9, **caractérisé en ce que** les paliers de la turbine (2) et/ou du moteur (5) comprennent des paliers à air, des paliers à gaz, ou une combinaison d'un palier à air ou à gaz et d'un palier à aimant.

11. Actionneur (10) selon l'une quelconque des revendications 1 à 10, **caractérisé en ce que** l'actionneur (10) comprend en outre un refroidisseur (3c) connecté entre la turbine (2) et la soupape de commande (4).

12. Procédé de commande d'un actionneur (10), lequel actionneur (10) comprend au moins un refroidisseur (3a, 3b), au moins un turbocompresseur (1 a, 1 b) avec une sortie pour transporter un gaz compressé dans ledit au moins un turbocompresseur (1 a, 1 b) jusqu'à au moins un refroidisseur (3a, 3b), une turbine (2), une soupape de commande (4), et un arbre (5a) auquel ledit au moins un turbocompresseur (1 a, 1 b) est connecté, dans lequel, dans le procédé, l'arbre (5a) est mis en rotation pour élever la pression du gaz devant être délivré à l'actionneur (10), et l'écoulement de gaz compressé produit par le turbocompresseur (1 a, 1 b) jusqu'à la turbine (2) est ajusté au moyen de ladite soupape de commande (4), **caractérisé en ce que** le procédé comprend en outre l'utilisation d'un moteur (5) pour mettre ledit arbre (5a) en rotation, et l'utilisation du gaz qui s'est écoulé à travers la turbine (2) pour refroidir au moins un des suivants :

- le moteur (5) du turbocompresseur ;
- un dispositif auxiliaire.

13. Système de commande pour un actionneur (10), lequel actionneur (10) comprend :

- au moins un refroidisseur (3a, 3b) ;
- au moins un étage de turbocompresseur (1 a, 1 b) avec une sortie pour transporter un gaz compressé dans ledit au moins un étage de turbocompresseur (1 a, 1 b) jusqu'à au moins un refroidisseur (3a, 3b),
- un arbre (5a) pour mettre en rotation ledit au moins un étage de turbocompresseur (1 a, 1 b) pour élever la pression du gaz devant être délivré à l'actionneur (10),
- une turbine (2), et
- une soupape de commande (4), au moyen de laquelle l'écoulement de gaz compressé produit par le turbocompresseur (1 a, 1 b) jusqu'à la turbine (2) est agencé pour être ajusté,

caractérisé en ce que le système de commande comprend en outre un moteur (5) agencé pour mettre en rotation ledit arbre (5a), et **en ce que** le système de commande est adapté à utiliser le gaz qui s'est écoulé à travers la turbine (2) pour refroidir au moins un des suivants :

- le moteur (5) du turbocompresseur ;
- un dispositif auxiliaire.

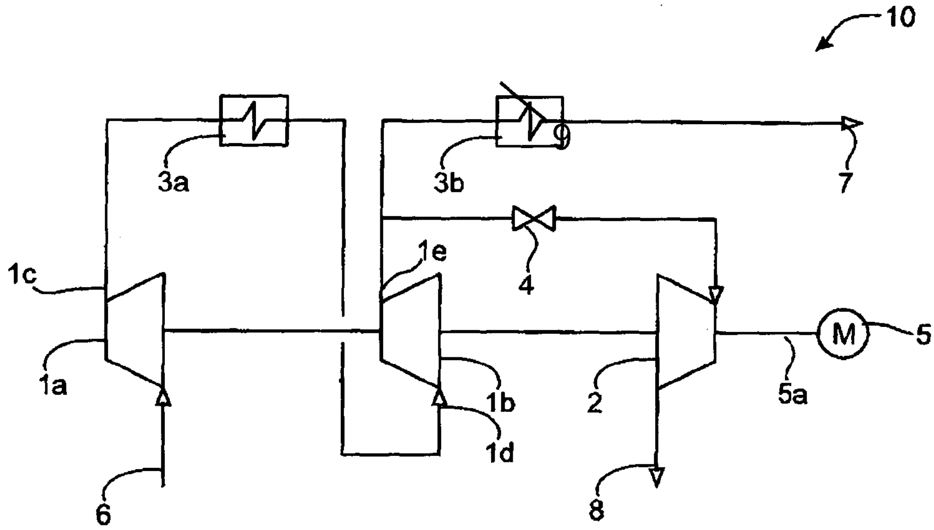

Fig. 1a

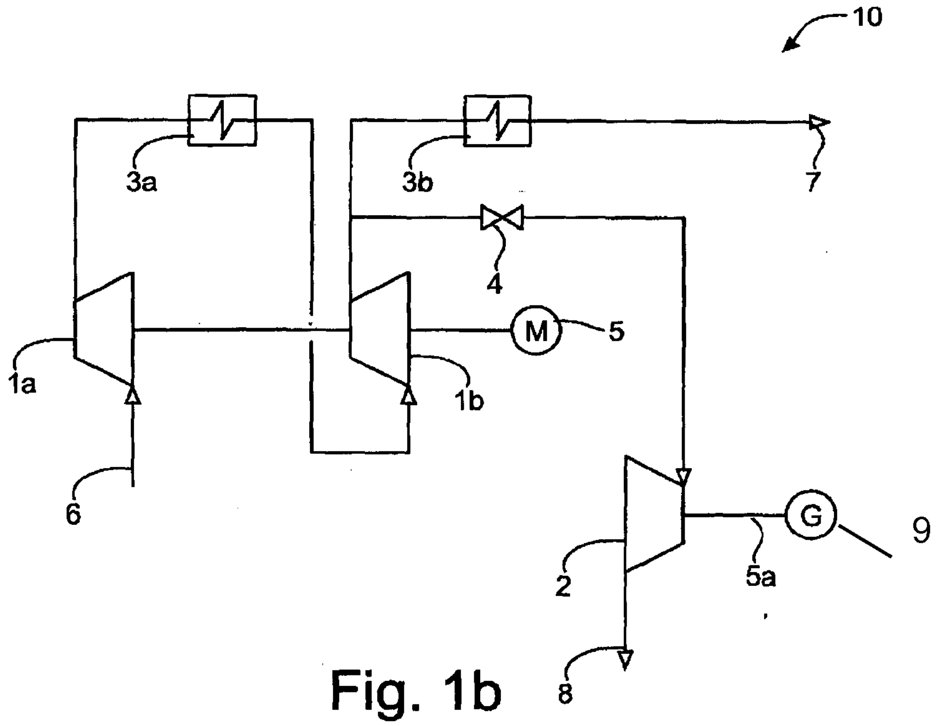

Fig. 1b

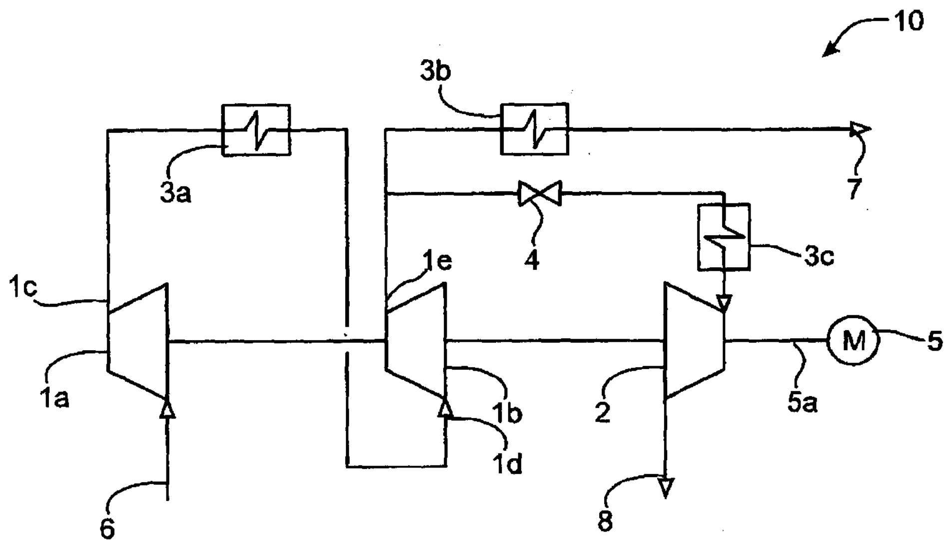

Fig. 1c

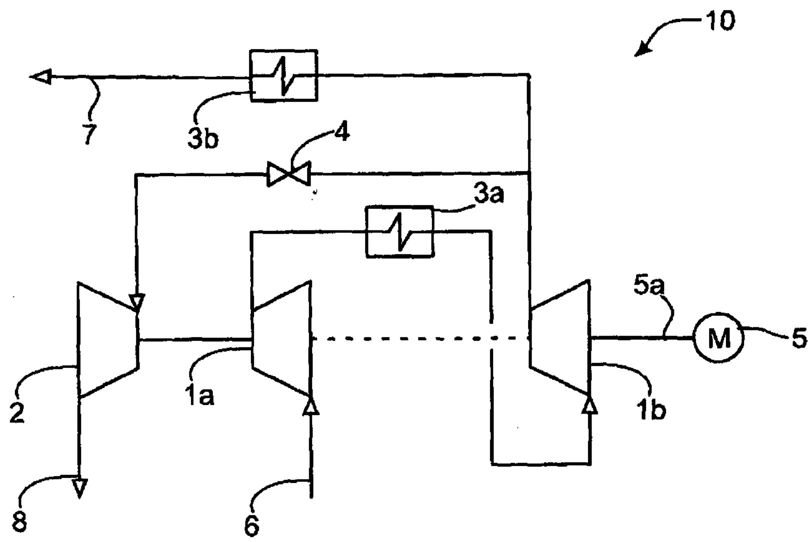

Fig. 1d

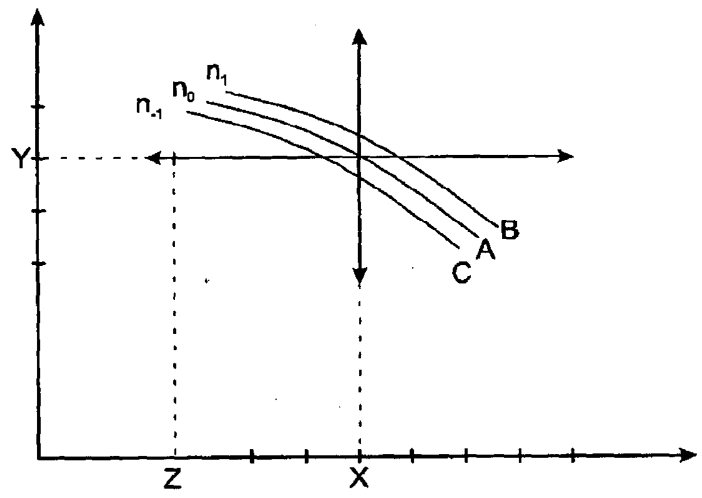

Fig. 2

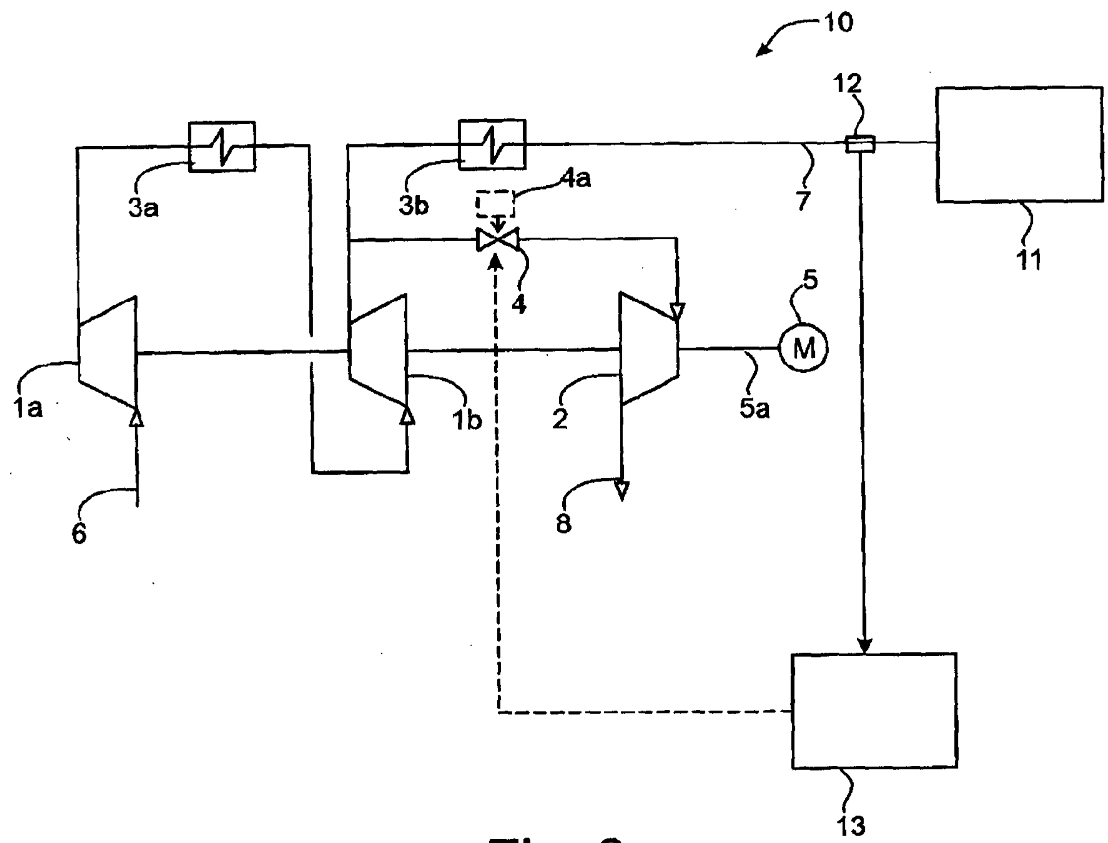

Fig. 3

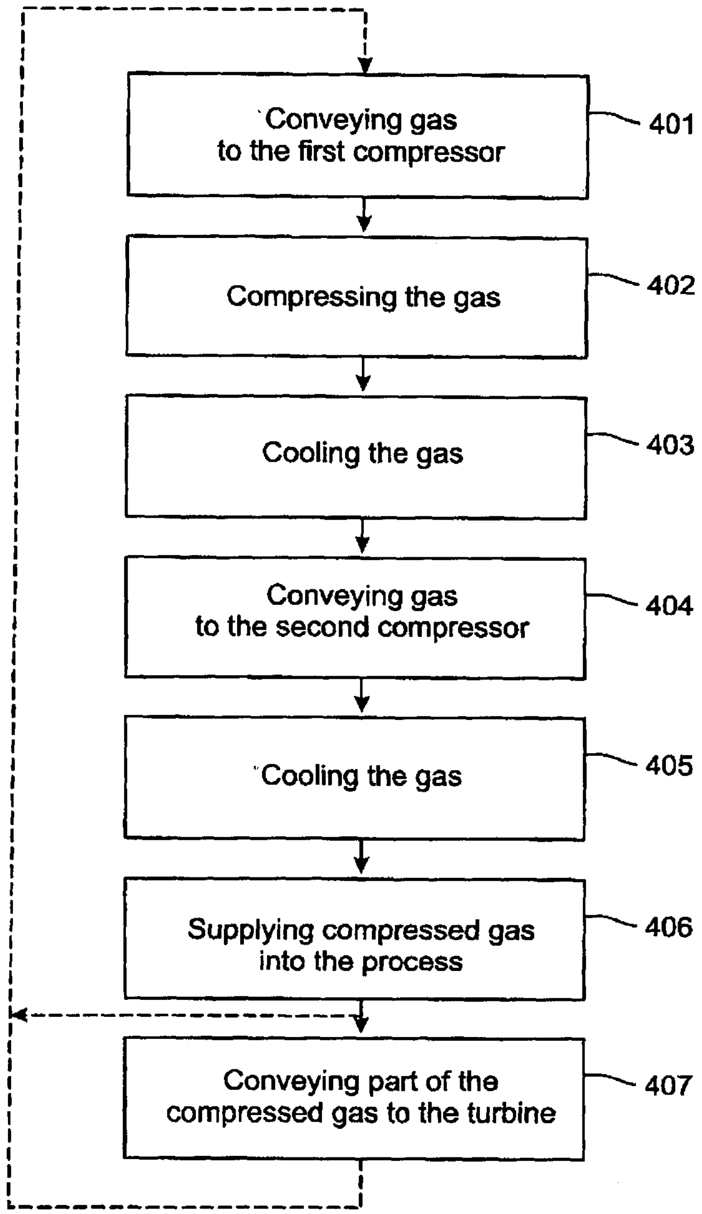
Conveying gas
to the first compressor
401
Compressing the gas
402
Cooling the gas
403
Conveying gas
to the second compressor
404
Cooling the gas
405
Supplying compressed gas
into the process
406
Conveying part of the
compressed gas to the turbine
407

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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Megoldás turbókompresszor szabályozására

SZABADALMI IGÉNYPONTOK

1. Szabályozó egység (10), amely tartalmaz:

- legalább egy hűtőberendezést (3a, 3b);
- legalább egy turbókompresszor fokozatot (1a, 1b), amelynek a legalább egy turbókompresszorban (1a, 1b) sűrített gáznak a legalább egy hűtőeszközbe (3a, 3b) történő továbbítására szolgáló kimenete van;
- tengelyt (5a), amely a legalább egy turbókompresszor(1a, 1b) forgatására szolgál annak érdekében, hogy növeljük a szabályozó egységbe (10) továbbitandó gáz nyomását;
- turbinát (2); és
- szabályozószelepet (4), amellyel a turbókompresszor (1a, 1b) által termelt sűrített gázt a szabályozandó turbinára (2) juttatjuk,

azzal jellemezve, hogy a szabályozó egység továbbá az említett tengelyt (5a) forgató motort (5) tartalmaz, és a szabályozó egység a turbinán (2) áthaladó gázt a következők közül legalább az egyik hűtésére használja fel:

- a turbókompresszor motorja (5);
- egy segédberendezés.

2. Az 1. igénypont szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a turbina (2) a tengelyhez (5a) van csatlakoztatva.

3. A 2. igénypont szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a szabályozó egység (10) továbbá tartalmaz egy generátort (9), amely a tengelyhez (5a) van csatlakoztatva.

4. Az 1. igénypont szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a szabályozó egység (10) továbbá tartalmaz egy generátort (9), amely teljesítményközlő kapcsolatban van a turbinával (2).

5. Az 1. – 4. igénypontok bármelyike szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a szabályozó egység (10) legalább egy első turbókompresszorral (1a) van ellátva, amelyen az említett gázkimenet (1c) van elrendezve, továbbá egy második turbókompresszor fokozattal van ellátva, amelynek gázbemenete (1d) van, valamint első hűtőeszköze (3a) van, amely a turbókompresszor első fokozatának kimenete (1c) és a második turbókompresszor bemenete (1d) között van elrendezve.

6. Az 5. igénypont szerinti szabályozó egység (10), ***azzal jellemezve***, hogy az említett szabályozószelep (4) az első hűtőeszközből (3) kiáramló gázt a turbinára (2) vezeti.

7. Az 1. – 4. igénypontok bármelyike szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a szabályozó egység legalább egy első turbókompresszor fokozattal (1a) van ellátva, amelyen az említett gázkimenet (1c) van elrendezve, valamint egy második turbókompresszor fokozata van, amelyen gázbemenet (1d), valamint gázkimenet (1e) van elrendezve, továbbá első hűtőeszközzel (3a) van ellátva, amely az első turbókompresszor fokozat kimenete (1c), valamint a második turbókompresszor fokozat bemenete (1d) között van elrendezve, továbbá második hűtőeszközt (3b), amely a második turbókompresszor kimenete (1e), valamint a szabályozó egység kimenete (7) között van elrendezve.

8. A 6. igénypont szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a szabályozószelep (4) úgy van elrendezve, hogy a második hűtőeszközből (3b) származó gázt a turbinára (2) vezeti.

9. Az 1. – 8. igénypontok bármelyike szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a motor (5) nagysebességű motor.

10. Az 1. – 9. igénypontok bármelyike szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a turbina (2) csapágyai és/vagy a motor (5) csapágyai légcsapágyak, gázcsapágyak vagy lég- vagy gázcsapágy és mágneses csapágy kombinációi.

11. Az 1. – 10. igénypontok bármelyike szerinti szabályozó egység (10), ***azzal jellemezve***, hogy a szabályozó egység (10) továbbá tartalmaz egy hűtőegységet (3c), amely a turbina (2) és a szabályozószelep (4) között van elrendezve.

12. Eljárás szabályozó egység (10) működtetésére, ahol a szabályozó egység (10) tartalmaz legalább egy hűtőelemet (3a, 3b), legalább egy turbókompresszort (1a, 1b), amelynek kimenete van az említett legalább egy turbókompresszor (1a, 1b) által sűrített gáz továbbítására a legalább egy hűtőegységbe (3a, 3b), továbbá turbinája (2), szabályozószelepe (4), és egy tengelye (5a) van, amelyhez a legalább egy turbókompresszor (1a, 1b) van csatlakoztatva, és ahol az eljárás során a tengelyt (5a) forgatjuk annak érdekében, hogy emeljük a működtető elembe (10) táplálandó gáz nyomását, továbbá a turbókompresszor (1a) által sűrített gáznak a turbinába (2) történő áramlását a szabályozószeleppel (4) szabályozzuk, ***azzal jellemezve***, hogy az eljárás során továbbá a motorral (5) az említett tengelyt (5a) forgatjuk, és a turbinán (2) átáramló gázt a következők közül legalább az egyik hűtésére használjuk:

- a turbókompresszor motorja (5);
- egy segédberendezés.

13. Szabályozórendszer szabályozó egységhez (10), ahol a szabályozó egység (10) tartalmaz:

- legalább egy hűtőberendezést (3a, 3b);
- legalább egy turbókompresszor fokozatot (1a, 1b), amelynek a legalább egy turbókompresszorban (1a, 1b) sűrített gáznak a legalább egy hűtőeszközbe (3a, 3b) történő továbbítására szolgáló kimenete van;
- tengelyt (5a), amely a legalább egy turbókompresszor (1a, 1b) forgatására szolgál annak érdekében, hogy növeljük a szabályozó egységbe (10) továbbítandó gáz nyomását;
- turbinát (2); és
- szabályozószelepet (4), amellyel a turbókompresszor (1a, 1b) által termelt sűrített gázt a szabályozandó turbinára (2) juttatjuk,

azzal jellemezve, hogy a szabályozórendszer továbbá az említett tengelyt (5a) forgató motort (5) tartalmaz, és a szabályozórendszer a turbinán (2) áthaladó gázt a következők közül legalább az egyik hűtésére használja fel:

- a turbókompresszor motorja (5);
- egy segédberendezés.